# Results of Model Intercomparison - Predicted vs. Measured System Performance

**Joshua Stein**
**Sandia National Laboratories**
**Albuquerque, New Mexico, USA**

**PV Performance Modeling Workshop**
**Sandia National Laboratories, Albuquerque, NM**
**September 22 & 23, 2010**

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# Goals and Objectives

- **Blind modeling study to illustrate the variability expected between PV performance model results**
  - What is the modeling uncertainty?
  - Do certain models do better than others?
  - How can performance modeling be improved?
  - What are the sources of uncertainty?

# Exercise Participants

- **17 Individuals submitted modeling results**
- **25 model sets of model results (template files)**
  - Some individuals submitted several sets of results
  - One individual used TMY weather file
- **Modelers were from a wide sample of the market landscape (except module manufacturers)**
  - Integrators, consultants, academia, national labs, state government

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# Models Used

- **5-Parameter Model (Univ. of Wisconsin)**
  - Solar Advisor Model
  - Other implementations (array temperature model)
- **PVSyst (V. 5.20, 5, and not specified)**
- **Sandia Photovoltaic Array Performance Model**
  - Solar Advisor Model (versions?)
  - PV Design Pro
  - Clean Power Research (PV Simulator ™)
  - Homemade versions
- **PVWatts**
  - Solar Advisor, other?
- **PVForm**
- **Internal Models**
  - UC Boulder
  - SRCL

# Models Used

## Model Forms

Implementation

| | 5-Par | 5-Par Modifed Temp | SAPM | PVSyst | PVWatts | Internal | Other |
|---|---|---|---|---|---|---|---|
| SAM | *** | | * | | * | | |
| PVWatts | | | | | * | | |
| PVForm | | | | | | | * |
| PVSyst | | | | ***** ** | | | |
| EES | | *** | | | | | |
| CECPV | * | * | | | | | |
| Internal | | | * | | | ** | |
| Other | | | * | | | | * |

Total = 24

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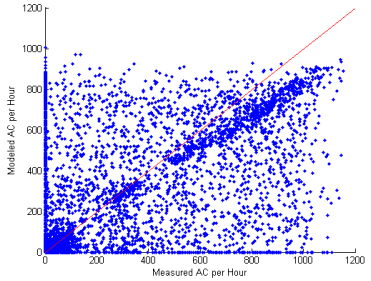
# Problems and Uncertainties

- **Problems encountered include**
  - Missing data (month of Dec for System 1) caused some problems
  - Several results were not usable (time mismatch?)
  - Oversized inverters
- **Uncertainties encountered include:**
  - Modules and inverters not in database
  - Not sure how to set derate factors
    - Some guessed
    - Some did not include derate factors

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# General Issues

- Not all models were able to simulate all systems.
- Some models (e.g., PVWatts on the web) cannot accept user-supplied weather data (SAM can)
- Not all participants included details about assumptions (e.g., derate factors)

- Each system has different set of models applied…

# Comparison Methods

- Hourly Energy Comparisons
- Monthly Energy Comparisons
- Annual  Energy Comparisons
- Module Temperatures

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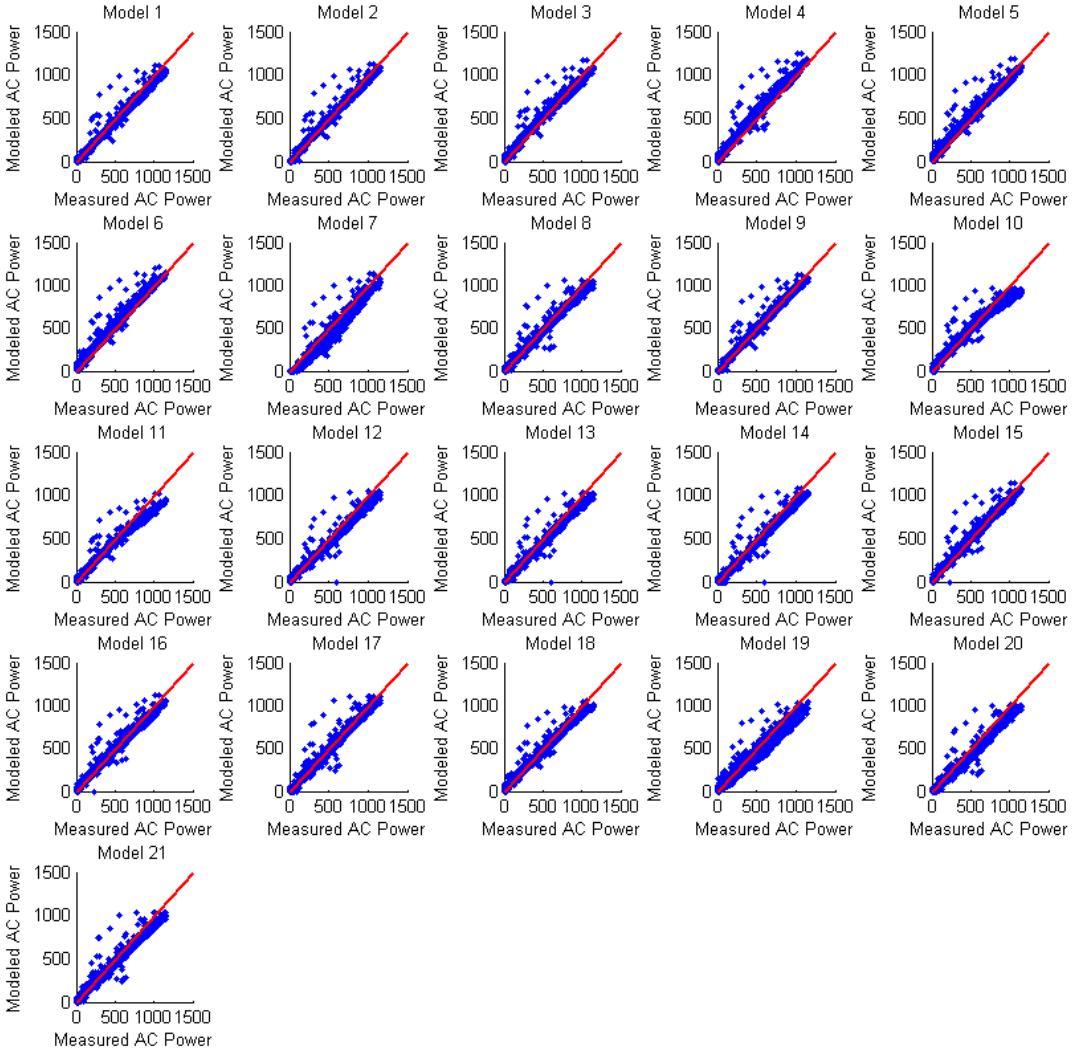
# Hourly Comparisons (System 1)

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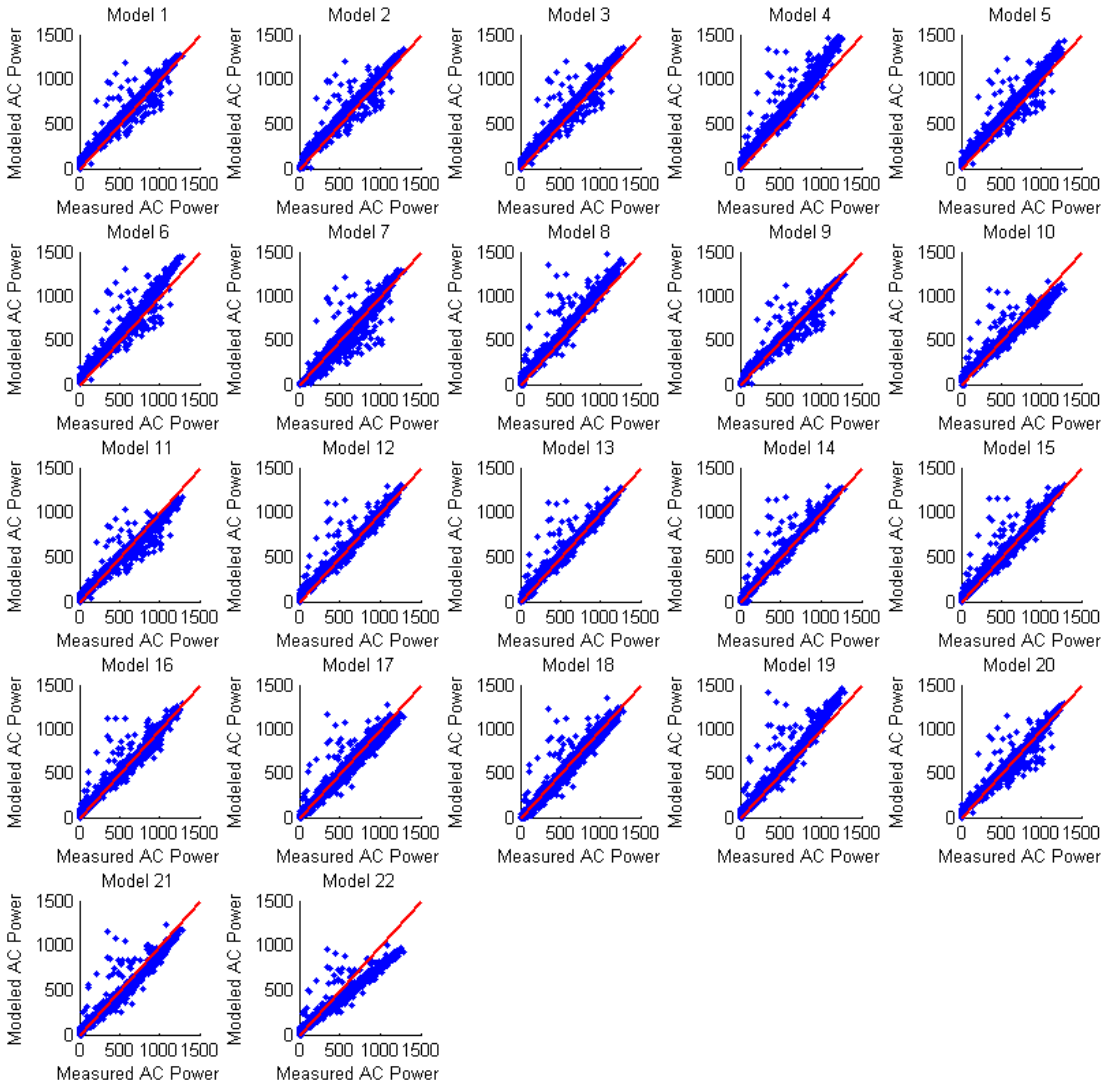
# Hourly Comparisons (System 2)

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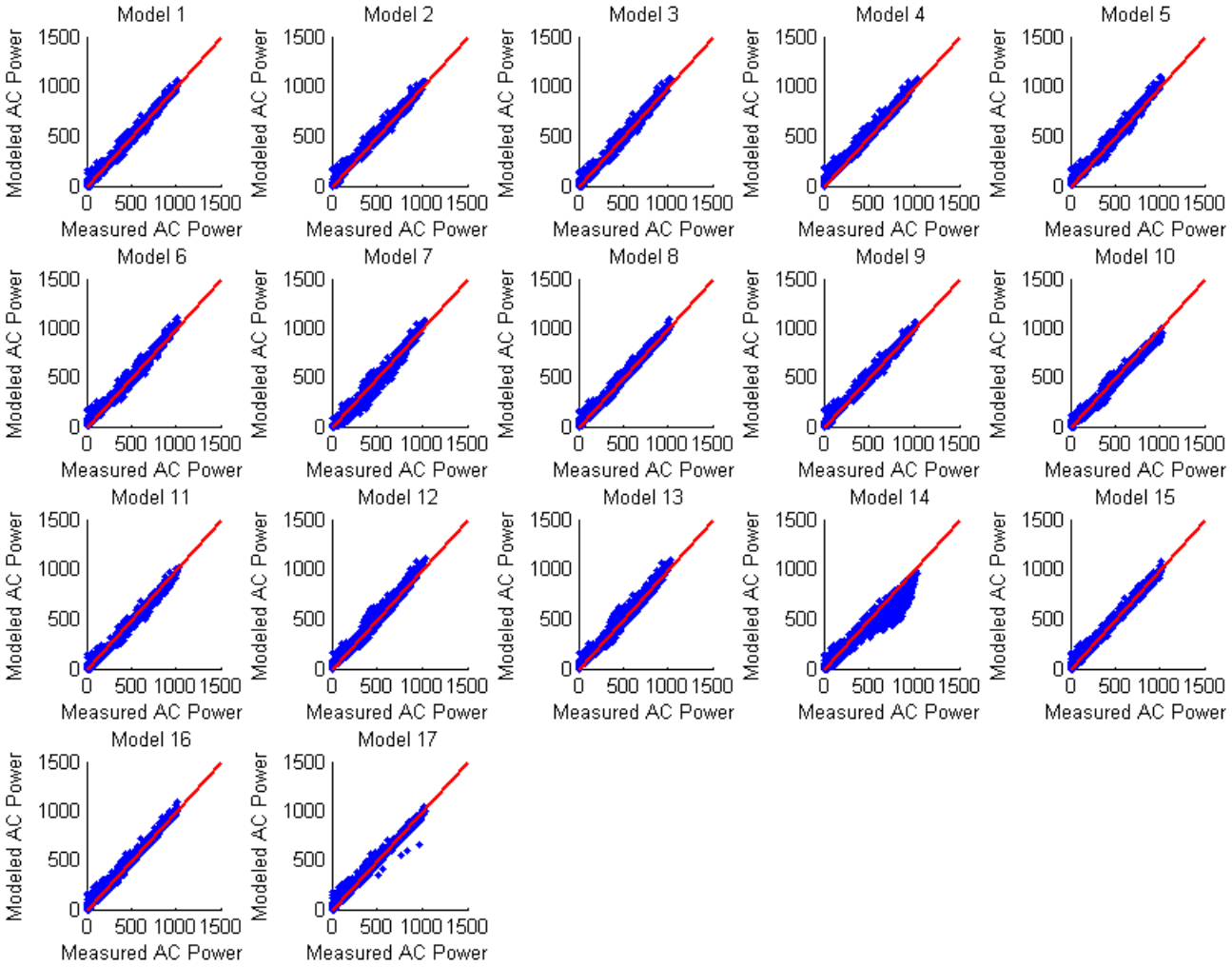
# Hourly Comparisons (System 3)

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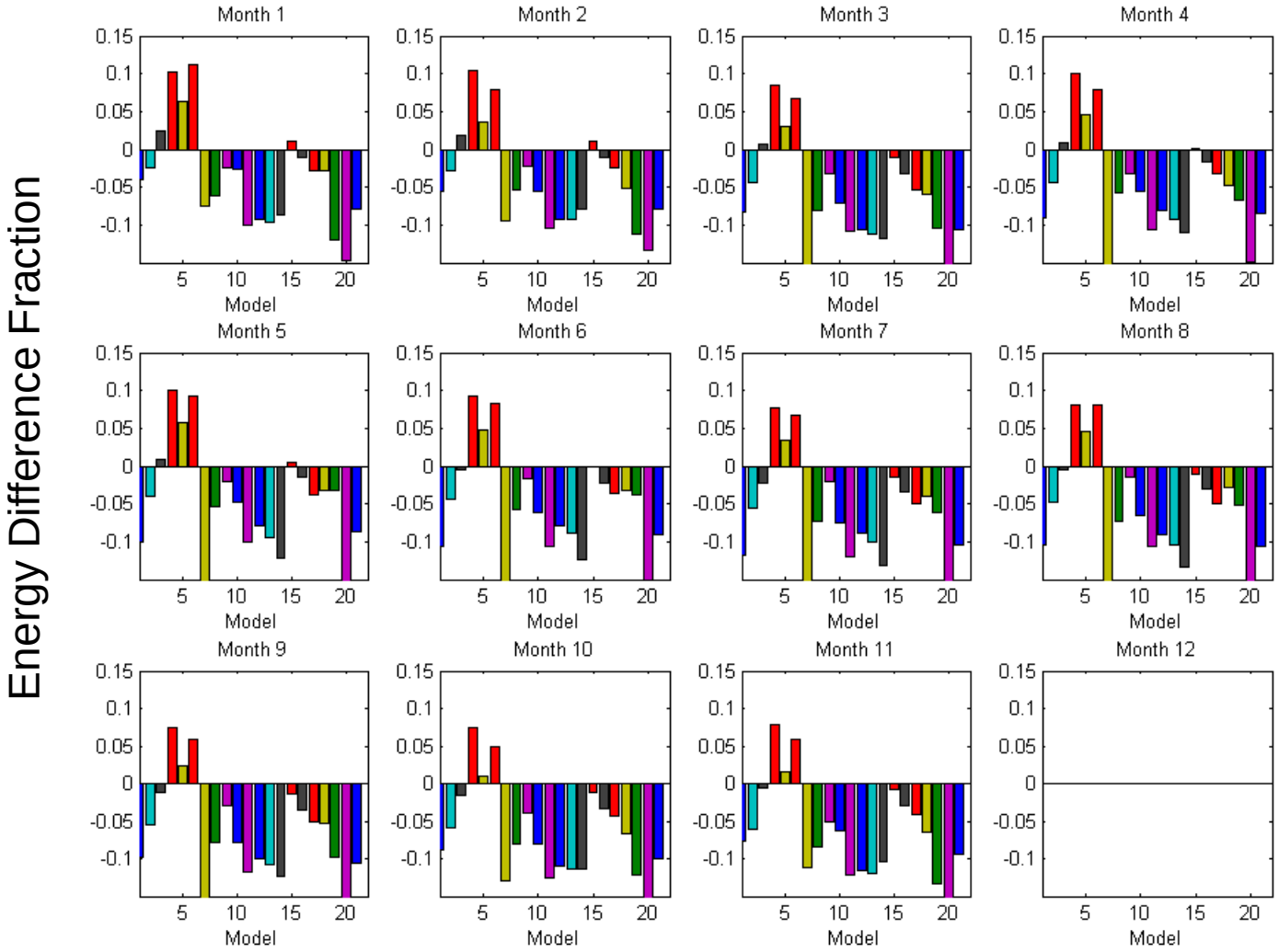
# System 1 Comparison by Month

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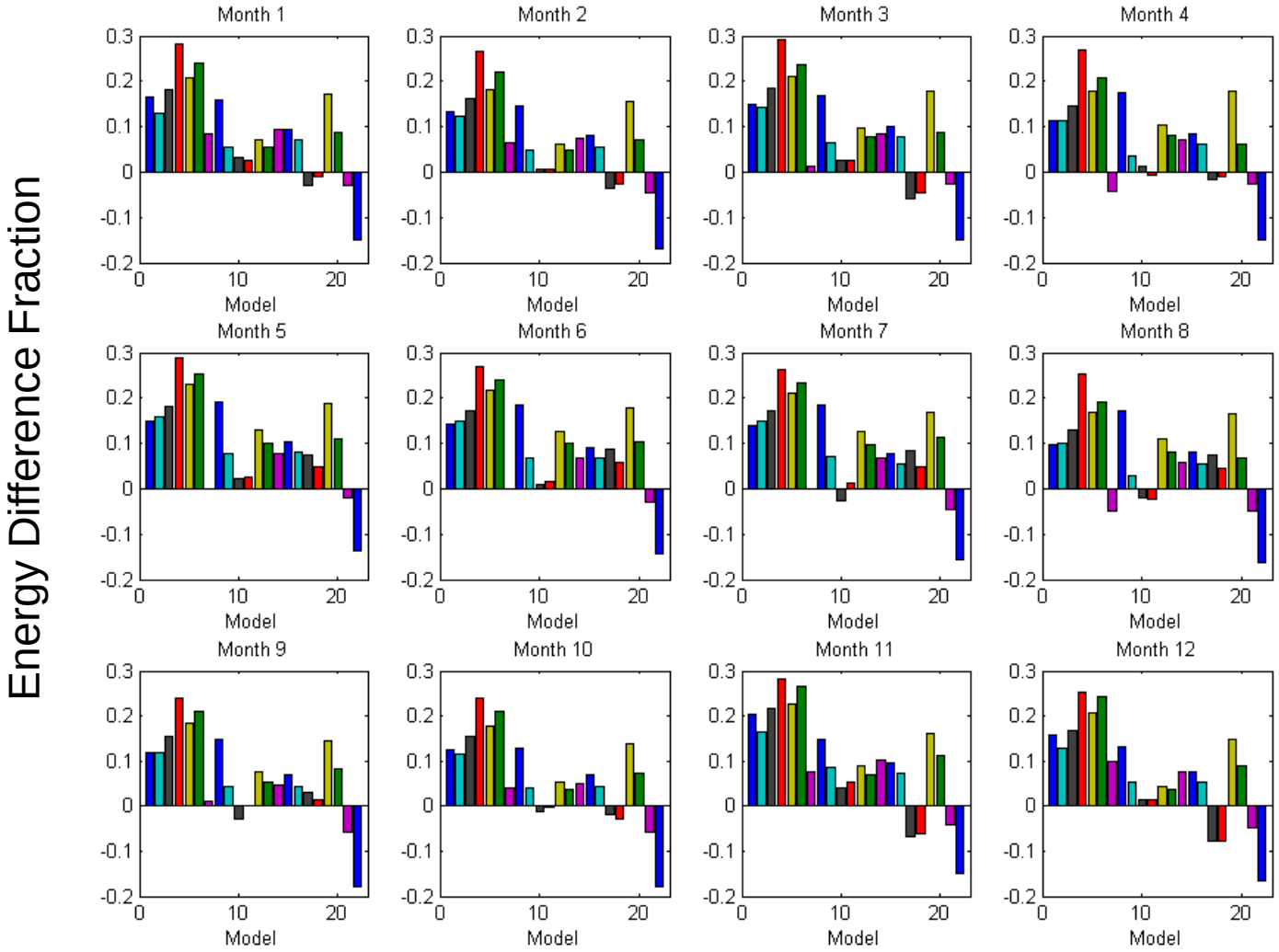
# System 2 Comparison by Month

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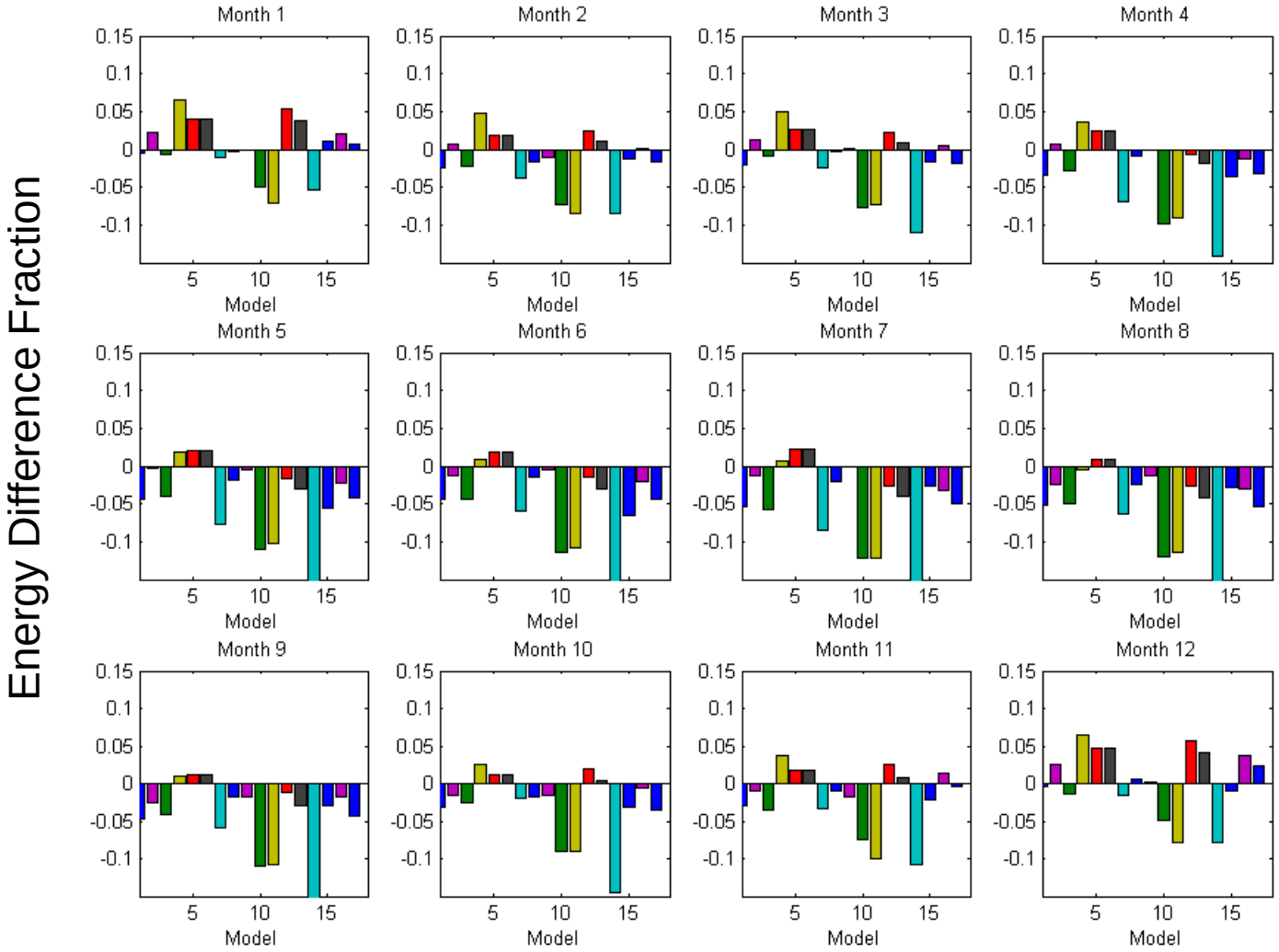
# System 3 Comparison by Month

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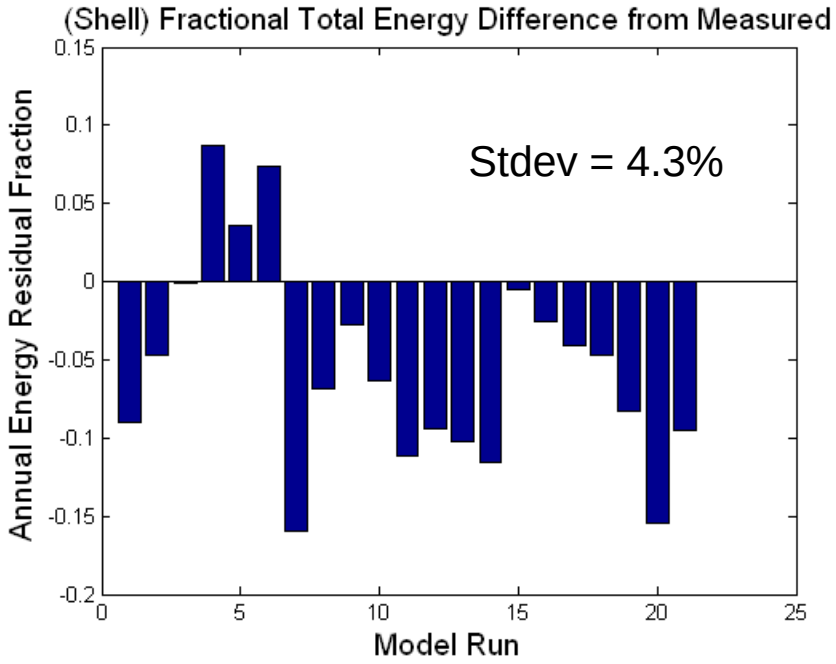
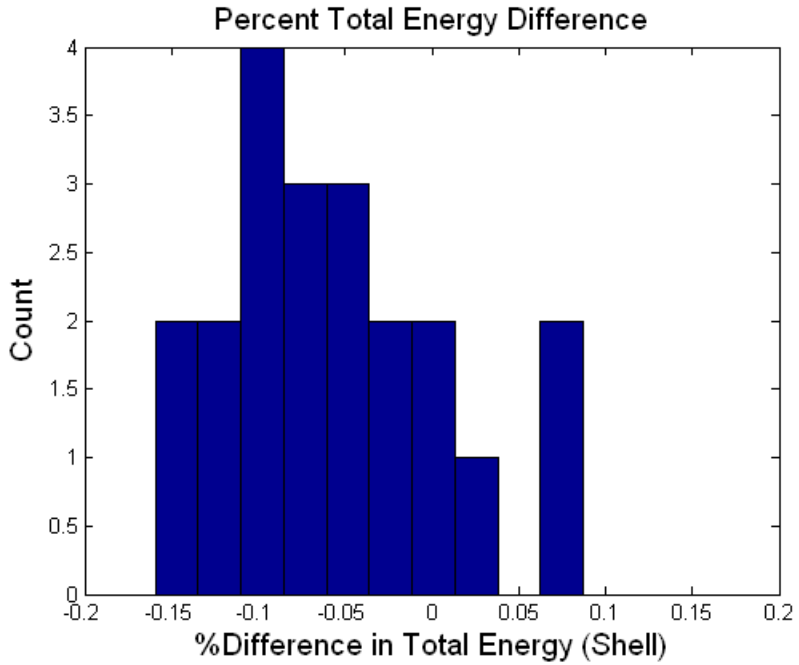
# Total Energy Residuals (System 1)

- Relative difference in total energy production:
  $(Energy_{mod} – Energy_{meas}) / Energy_{meas}$

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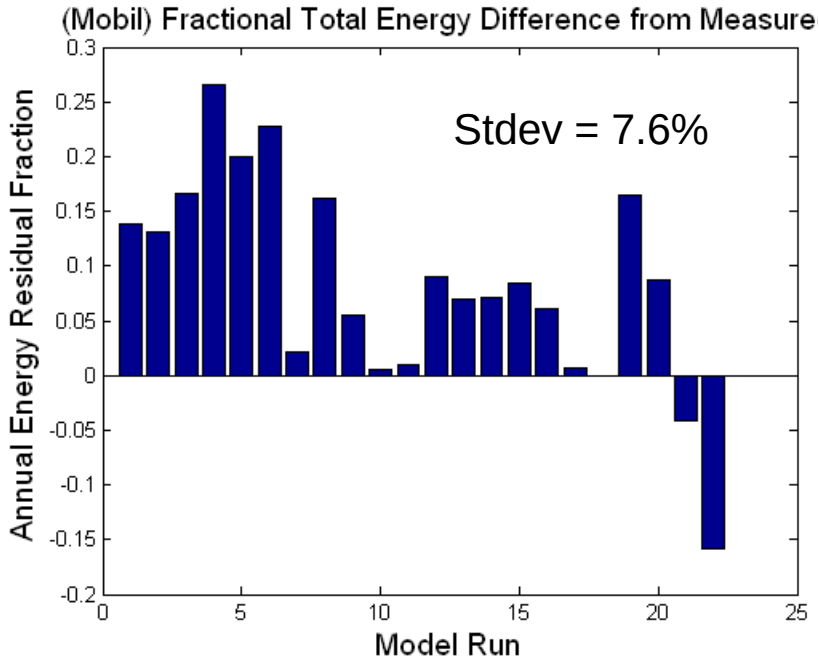
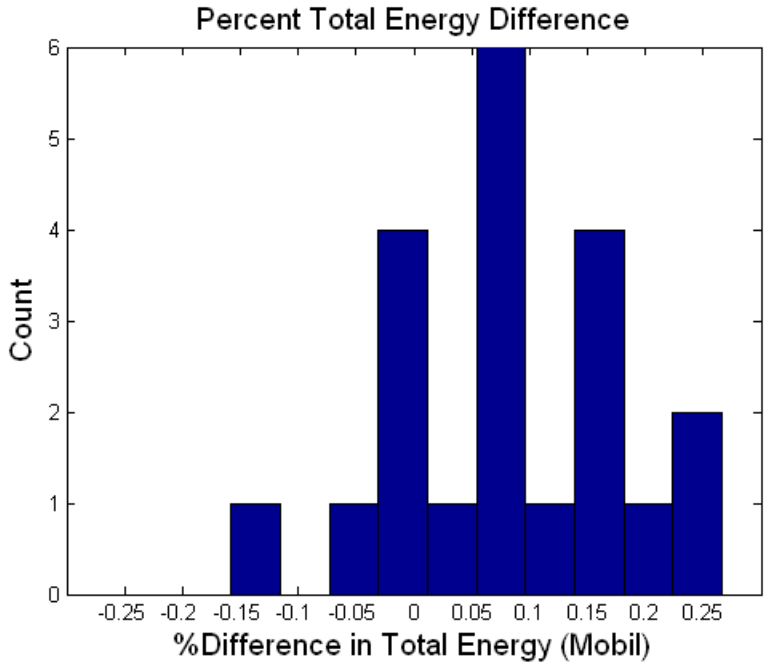
# Total Energy Residuals (System 2)

- Relative difference in total energy production:
  $(Energy_{mod} – Energy_{meas}) / Energy_{meas}$




Inverter load = ~18 W

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# Total Energy Residuals (System 3)

- Relative difference in total energy production:
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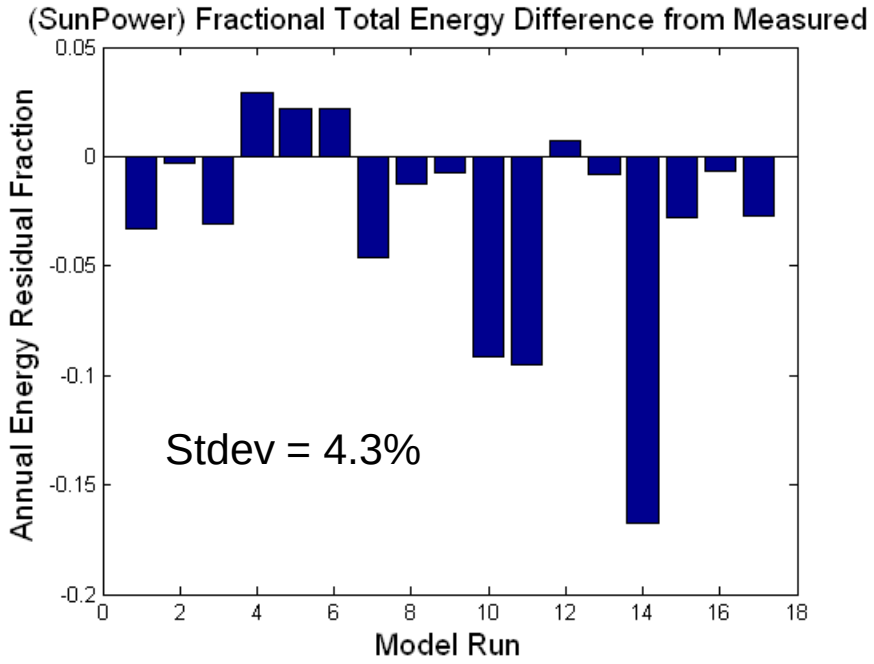


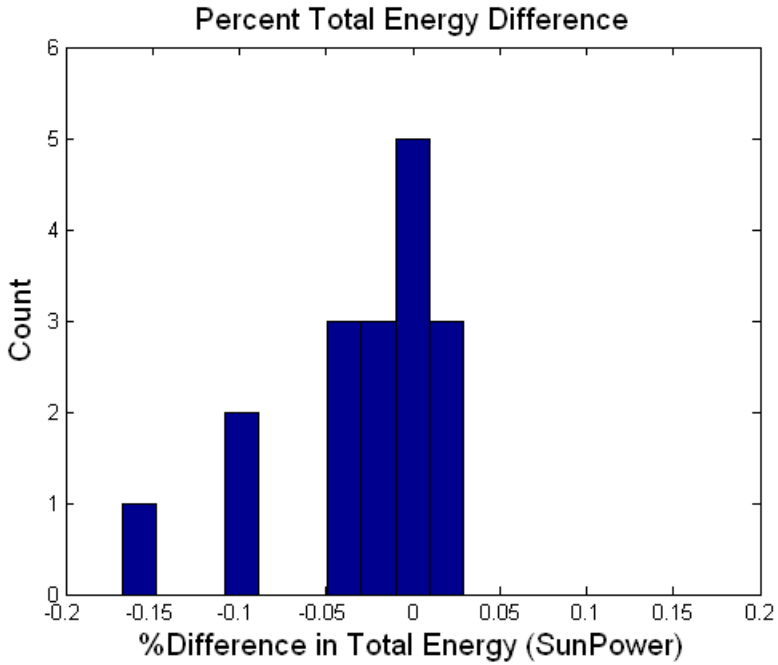


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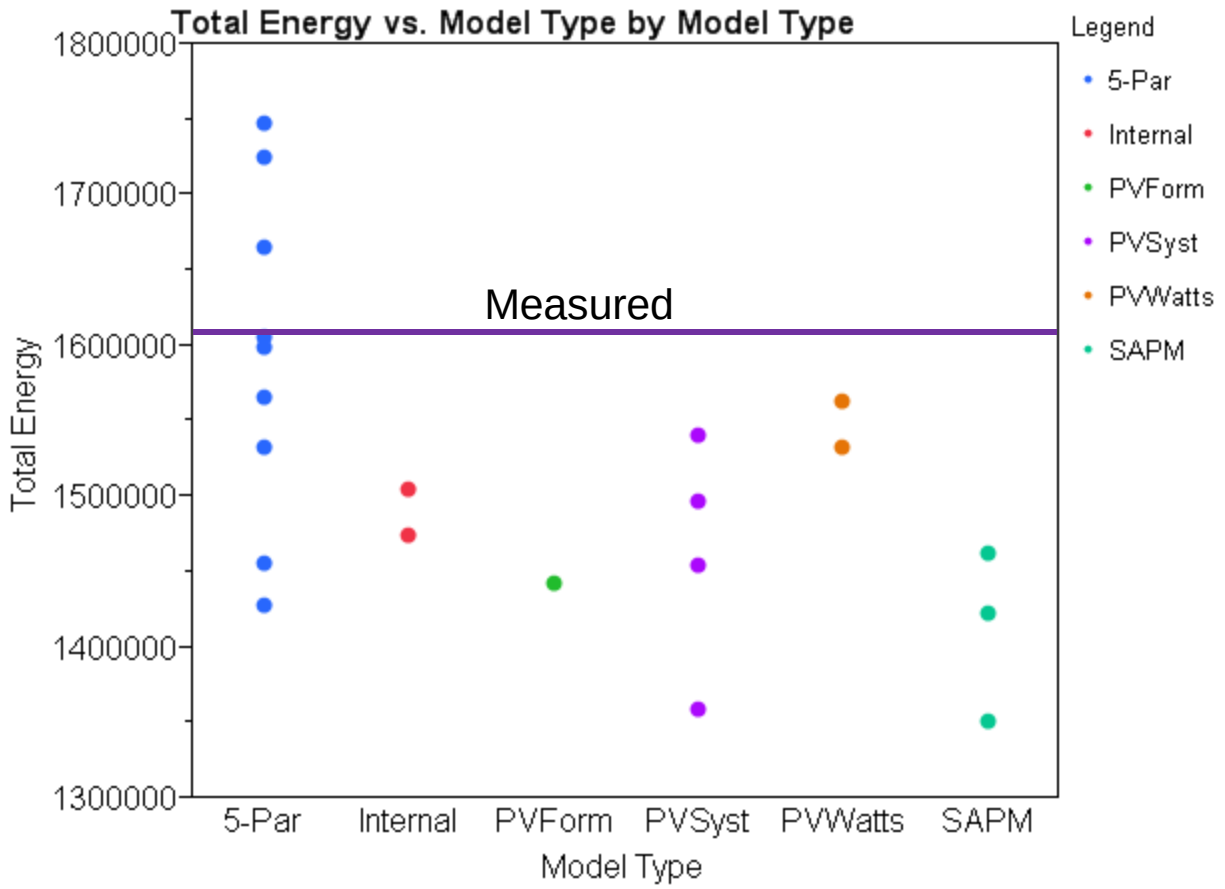
# System 1 Totals by Model Type

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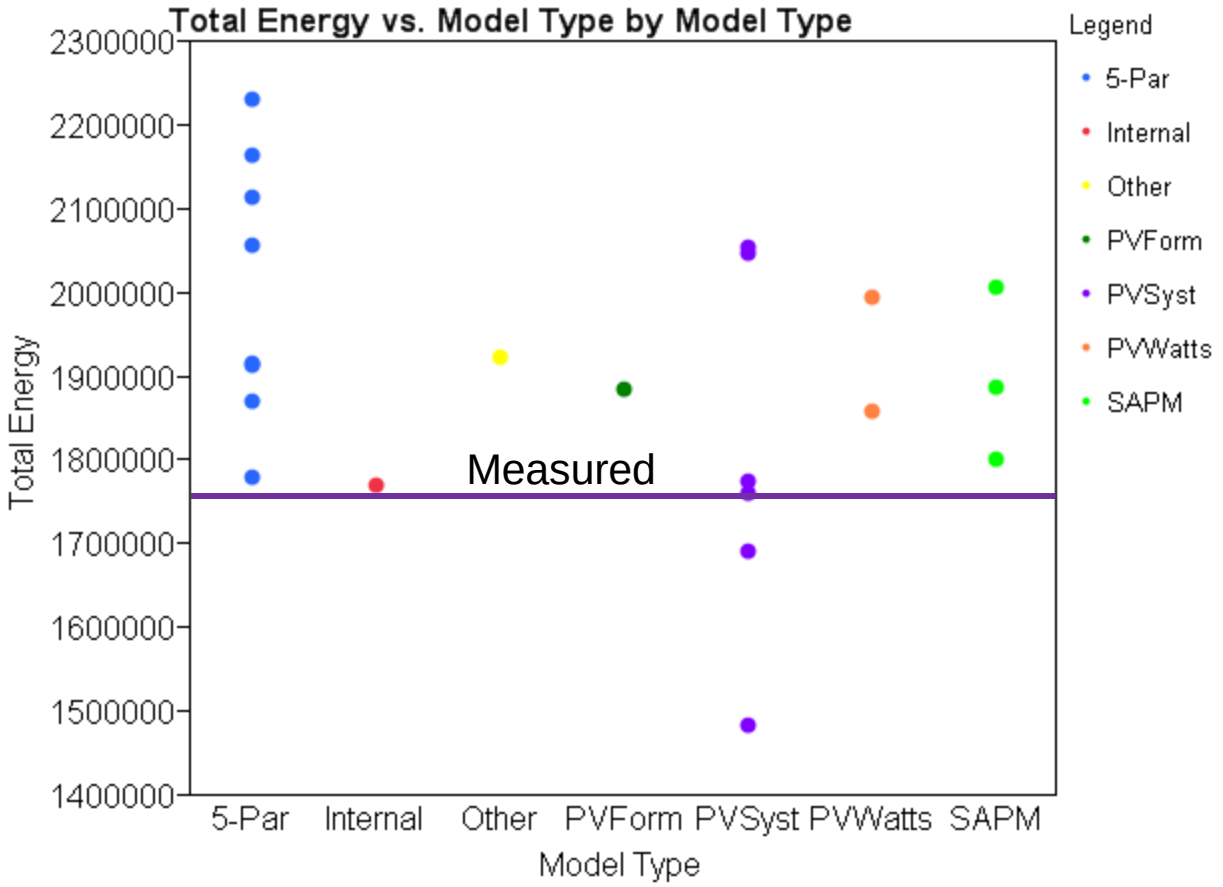
# System 2 Totals by Model Type

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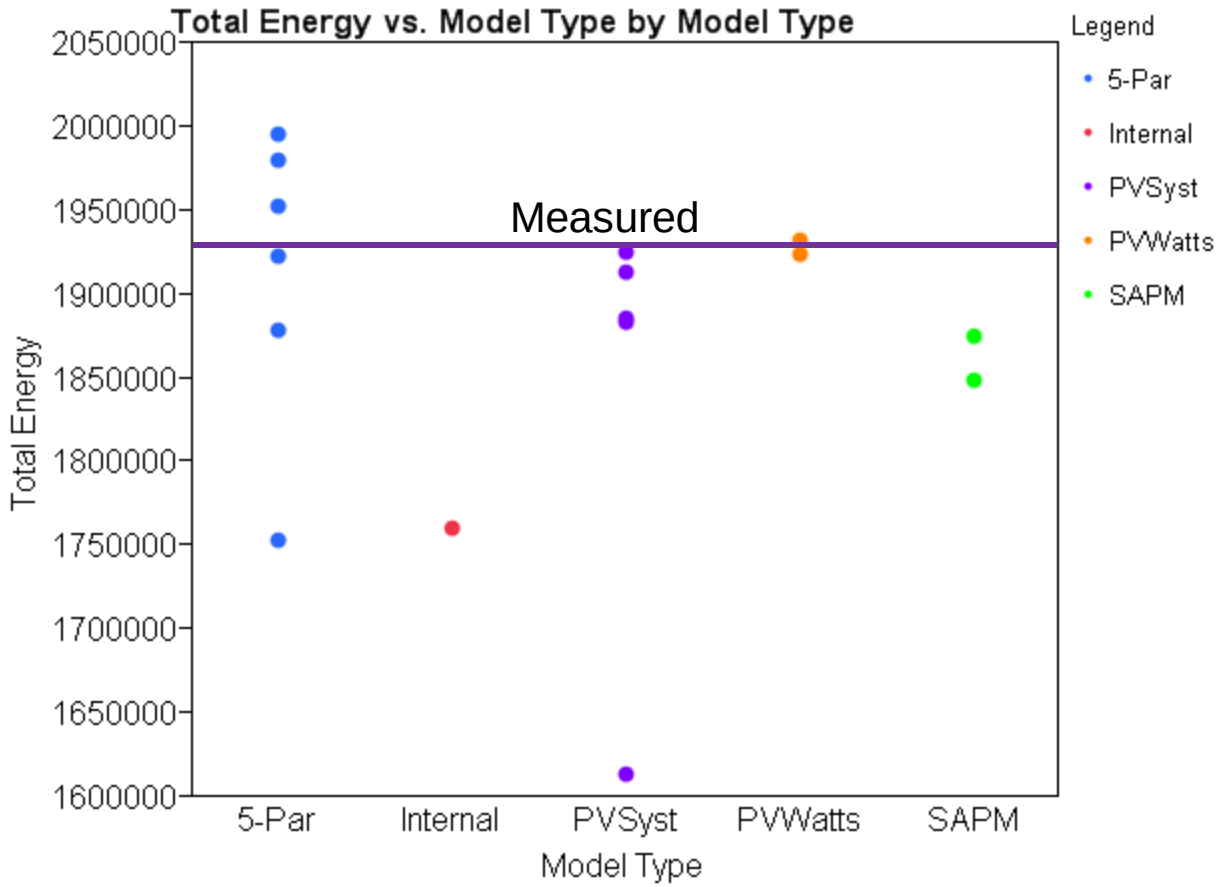
# System 3 Totals by Model Type

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# Module Temperature Results

- **Model Output: Module temperature or cell temperature?**
  - Module backside temperature is measured quantity

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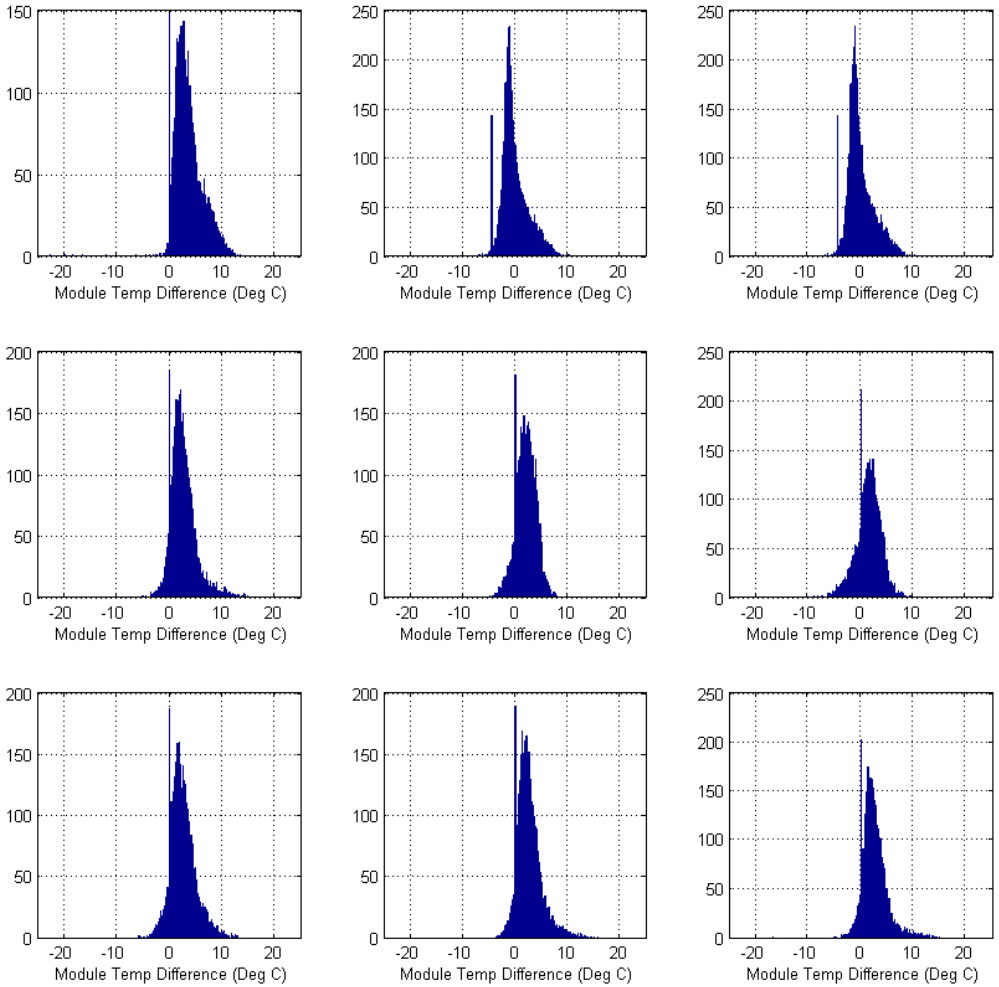
# Example Module Temperature Results System 3




- Most module temperature models appear to behave well.
- Mean bias error range: (-0.17 – 3.6 deg C
- Stdev range: (2-2.5 deg C

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# Preliminary Conclusions

- **Large variation seen in model results**
- **Variation not entirely consistent across systems**
- **Uncertainty in assigning derates**
- **Discomfort when components are not included in database.**
  - Is there comfort when the components are in the database???
- **Residual analysis will help to uncover additional patterns in the models.**